SPECIFICATION

HIGH ENERGY SUPPLY APPARATUS, METHOD OF FORMING CRYSTALLINE FILM AND METHOD OF MANUFACTURING THIN FILM ELECTRONIC DEVICE

Technical Field

The present invention relates to a high energy supply apparatus such as a laser irradiation apparatus as a representative, a method of forming a crystalline film by using the high energy supply device, and a method of manufacturing a thin film electronic device comprising the crystalline film formed by the method.

Background Art

As the screen size and resolution of a liquid crystal display (LCD) increase, a driving system therefor is transferred from a simple matrix system to an active matrix system, thereby enabling display of large volumes of information. The active matrix system permits LCD having over several hundreds of thousands of pixels and comprises a switching element such as a thin film transistor (TFT) for each pixel. As substrates for various types of LCD, transparent insulating substrates

1

such as a fused quartz plate, a glass plate, and the like which enable transmission type display are used. As an active layer of such a TFT, a semiconductor film of amorphous silicon (a-Si), polycrystalline silicon (poly-Si) or the like is generally used. When not only the pixel switching element but also a driving circuit are integrally formed by using TFT, it is necessary and essential to use polycrystalline silicon exhibiting a high operation speed. In use of the polycrystalline silicon film as the active layer, TFT is generally formed by using a fused quartz plate as a substrate in a manufacturing method referred to as a high-temperature precess in which the highest temperature of the process exceeds 1000°C. In this case, the mobility of the polycrystalline silicon film is about 10 $cm^2 \cdot V^{-1} \cdot S^{-1}$ to 100 $cm^2 \cdot V^{-1} \cdot S^{-1}$. On the other hand, in use of an amorphous silicon as the active layer, the highest temperature of the process is as low as about 400°C, and a glass substrate is thus generally used. The mobility of the amorphous silicon film is about 0.1 $cm^2 \cdot V^{-1} \cdot S^{-1}$ to 1 $cm^2 \cdot V^{-1} \cdot S^{-1}$.

Advances in enlargement of LCD display screens and reduction of the cost require the use of a low-cost glass plate as an insulating substrate. However, as described above, the amorphous silicon film is significantly

2

inferior to the polycrystalline silicon film in electrical properties, and has problems of a low operation speed, etc. On the other hand, the polycrystalline silicon TFT produced by the high temperature process comprises a fused quartz plate, and thus has the problem of causing difficulties in enlarging a LCD and reducing the cost thereof. Therefore, there is strong demand for a technique for forming a thin film semiconductor device comprising a crystalline semiconductor film such as a polycrystalline silicon film or the like as an active layer formed on a usual glass substrate. In use of a usual large glass substrate having high mass productivity, the highest temperature of the process is limited to about 400°C or less in order to avoid deformation of the substrate. This is referred to as a "low-temperature process poly-Si TFT" and now under development. Eventually, the most important technical problem of the low-temperature process poly-Si TFT lies in how to form an excellent crystalline film by a processing temperature of 400°C or less, i.e., how to improve an apparatus for forming a good crystalline film. Solution to such a problem enables not only the formation of a good TFT and a LCD comprising this TFT but also significant improvements in performance of all electronic devices such as solar

3

cells and semiconductor device circuits, which are formed by using crystalline films. At the same time, this enables a further reduction of the cost.

First prior art is disclosed in SID (Society for Information Display) '93 Digest P. 387 (1993) in which a crystalline film is formed at a low temperature, and a thin film electronic device comprising the film is formed. In this prior art, a polycrystalline silicon film is formed as the crystalline film, and a TFT is formed as the thin film electronic device. The crystalline film is formed by depositing an a-Si film of 50 nm by a low-pressure chemical vapor phase deposition process (LPCVD process) using monosilane (SiH_4) as a raw material at a deposition temperature of 550°C, and then applying a laser beam to the thus-formed a-Si film. Although not disclosed in this digest, irradiation of the laser beam is carried out by the laser irradiation apparatus 101 shown in Fig. 1. The laser irradiation apparatus 101 comprises a laser light emission source 102 and a laser irradiation chamber, a substrate having a material 103 to be irradiated such as the a-Si film which is placed on the surface thereof being disposed on a stage 105 provided in the laser irradiation chamber. In the laser irradiation chamber is provided a laser incident window comprising quartz glass or the like

4

at a position opposite to the stage so that a laser beam 107 is incident through the laser incident window 106. The distance between the laser incident window and the substrate 104 is generally about 1 cm. The material to be irradiated is irradiated with a laser beam at a stage temperature of room temperature to about 400°C under pressure of vacuum to atmospheric pressure.

After the poly-Si film comprising a crystalline film is obtained as described above, the thin film electronic device (TFT) is formed by using the poly-Si film. Specifically, after the poly-Si film is processed to a desired shape, an oxide film functioning as a gate insulating film is deposited by a PECVD process or the like. A gate electrode is formed on the gate insulating film by using tantalum (Ta), and then a source and a drain for a transistor are formed, in a self alignment manner, by implanting donor or acceptor impurities into the polycrystalline silicon film using the gate electrode as a mask. Impurities are implanted by an ion doping method using a mass non-separation type implantation apparatus and phosphine (PH_3) and diborane (B_2H_6) as raw material gases which are diluted with hydrogen. The ions injected are activated at 300°C. The insulating layer is then deposited, and electrodes and wiring are formed by using

indium tin-oxide (ITO) and aluminum (Al) to complete a TFT.

Second prior art for obtaining a crystalline semiconductor film at a low temperature is disclosed in Japanese Patent Laid-Open No. 7-99321. In this second prior art, an a-Si film is formed and then irradiated with a laser beam to obtain a crystalline film. Irradiation of the laser beam is carried out under pressure of vacuum or in an inert gas atmosphere. In fact, the same publication discloses in paragraph [0009] the following. "At least the surface layer of the semiconductor thin film formed on the substrate is melted and recrystallized under reduced pressure or in an inert gas atmosphere, and the substrate (1) having the melted and recrystallized semiconductor film formed thereon is transferred to the step of forming an insulating film on the melted and recrystallized semiconductor film while being maintained under reduced pressure or in an inert gas atmosphere." In the second prior art, a TFT is formed by a manufacturing method basically the same as the first prior art using the thus-obtained polycrystalline silicon film. Eventually, in both prior arts, a crystalline film is obtained by irradiating a silicon film with a laser beam using the laser irradiation device shown in Fig. 2 under pressure of

6

vacuum to atmospheric pressure or in an inert gas atmosphere.

However, the above-mentioned prior arts are considered as having the following problems:

Problem 1) Irradiation under atmospheric pressure causes contamination of the crystalline film with impurities such as oxygen and nitrogen or dust. Particularly, when the crystalline film comprises a semiconductor or a metal, contamination with oxygen or dust brings about significant deterioration in the physical properties of the thin film formed.

Problem 2) A gas frequently used in crystallization under an inert gas atmosphere is nitrogen. Since nitrogen has high reactivity to semiconductors such as silicon and the like and metals such as tantalum and the like, a high-purity crystalline semiconductor film and crystalline metallic film cannot be obtained.

Problem 3) Irradiation under vacuum necessitates that a laser irradiation chamber with high sealing performance is provided, and a large scale evacuation device such as a turbo-molecular pump is added to a laser irradiation apparatus. This brings about an increase in the cost of a thin film electronic device comprising a crystalline thin film, and a decrease in productivity.

Problem 4) In melt crystallization, the component elements of the melted material irradiated with a laser beam are invariably scattered or evaporated. This phenomenon is particularly remarkable in laser irradiation under vacuum because melting under vacuum causes the formation of a deposited film. As a result, a film of the material irradiated with a laser beam is formed on the laser incident window of the laser irradiation apparatus. Fig. 1 shows a scattered molecule 108 in this state. Evaporation of the material 103 to be irradiated and the formation of a film on the laser incident window represent attenuation of the laser energy applied to the material to be irradiated at each time of laser irradiation. Namely, the prior arts are incapable of obtaining a crystalline film having good characteristics and cause large variations in film quality.

Problem 5) When high energy is supplied to the material to be irradiated by laser irradiation or the like to progress melt crystallization, as the supplied energy increases, the quality of the crystalline film obtained is improved. However, in irradiation under vacuum, problem 4) becomes significant as the supplied energy increases. This makes it substantially impossible to increase the supplied energy in irradiation under vacuum and improve

the quality of the crystalline film obtained.

Problem 6) In laser irradiation under vacuum or in an inert gas atmosphere, at the end of melt crystallization by irradiation (at the time the material to be irradiated with a laser beam is transferred from a solution state to a crystal solid state), the surface is reconstructed to minimize the surface energy, and many chemically active unpaired bonding electrons remain on the surface. The reconstructed surface having unpaired bonding electrons has a structure completely different from that of the internal crystal, and thus shows an energy band diagram greatly different from that of the internal crystal. In both cases of a semiconductor thin film and a metallic thin film, many electronic devices employ the surfaces of these films. For example, in a field effect transistor (FET) comprising a semiconductor thin film, an inversion layer is formed on the surface of the semiconductor to control the transfer process of electrons and holes in the semiconductor. In metal wiring, of course, a current flows through the surface of the metallic thin film. In a device (for example, a mirror and a metal catalyst) which employs the optical properties or chemical properties of a thin film, the characteristics thereof are determined by the surface. If the important surface having unpaired

bonding electrons is greatly different from the inside due
to reconstruction, the physical properties of the surface
also greatly change (generally deteriorate). For example,
in a FET comprising a semiconductor thin film, the
mobility in the inversion layer is decreased to several
tens to several % of the mobility of the inside of the
semiconductor according to the surface state. The same
phenomenon is observed in a metallic thin film (for
example, the electric conductivity of the metallic thin
film changes). As described above, control of the surface
plays an important part in obtaining a good crystalline
film. However, in a conventional crystallization method,
such control is not sufficiently made, and thus an
excellent crystalline film cannot be obtained. Further,
the characteristics of the crystalline film greatly vary
with variations in the state of the reconstructed surface
at each time of melt crystallization.

Accordingly, the present invention is aimed at
solving the above problems, and an object material of the
invention is to provide a high energy supply apparatus
such as a laser irradiation apparatus as a representative,
a method of forming a good crystalline film using the high
energy supply apparatus at a relatively low temperature,
and a method of manufacturing a thin film electronic

device comprising the crystalline film formed by the method.

Disclosure of the Invention

Summary of the Invention
(1-1. Control of atmosphere in melt crystallization)

In the present invention, thin films of a semiconductor such as silicon and a metal such as tantalum are deposited on various substrates in a first step, and at least the surface layers of these thin films are partially melted and then crystallized through a cooling solidification process (abbreviated to "melt crystallization" hereinafter) to form various crystalline films in a subsequent second step. Substrates to which the present invention can be applied will be described in detail in Chapter (2-1), and the thin films will be discussed in Chapter (2-2). The crystalline films mean films in a single crystal state, a polycrystal state or a mixed crystal state wherein a crystal and an amorphous material are mixed. Melt crystallization is achieved by supplying high energy such as a laser beam to the thin films. Possible forms of high energy include electromagnetic waves such as light, X-rays, and gammer

11

rays as representatives; charged particle flows such as
proton rays, electron rays, alpha rays, and the like;
neutral elementary particle rays such as neutron rays and
neutral meson rays as representatives. The elementary
particle rays have the advantage that high energy can
simply be supplied to the thin films through strong or
weak interaction. Even when the thin films have low
electric conductivity, the neutral elementary particle
flows containing electromagnetic waves (photon) do not
apply unnecessary charge to the thin films and thus do not
electrically damage the thin films during supply of high
energy. Particularly when the thin films are intrinsic or
nearly intrinsic semiconductor films, this is important
because these thin films have low electric conductivity.
The charged particle flows have the advantages that they
can easily be formed by generating a plasm of atoms, and
that the directions of the charged particle flows can
easily be controlled. In view of the ease of handling
such as formation and direction control, or safety for
living bodies, an optimum form of high energy material is
electromagnetic waves with a wavelength of about 10 nm to
about 10 μm, i.e., so-called light. Light can be
classified to laser beams and nonlaser beams both of which
can be used as forms of high energy.

In the second step, metal crystallization proceeds in an atmosphere containing hydrogen such as a mixed gas containing hydrogen molecules (H_2) and an inert gas; a mixed gas containing a hydrogen halide such as hydrogen fluoride (HF), hydrogen chloride (HCl) or the like and an inert gas; a mixed gas containing an inert gas and an acid such as nitric acid (NHO_3), sulfuric acid (H_2SO_4) or the like; a mixed gas containing an inert gas and a gas containing as a hydride of the component element of a thin film of a semiconductor or the like, such as silane (SiH_4, Si_2H_6) as a representative. As the inert gas, nitrogen (N_2), single rare gases such as helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe) and the like; mixed gases containing these gases, all gases chemically inert for thin films subjected to melt crystallization and mixed gases containing these gases and the above inert gases can be used.

Progress of melt crystallization of a thin film in an atmosphere containing an inert gas and hydrogen has the advantages that it is possible to significantly decrease contamination of the thin film with impurities such as oxygen and dust particles floating in air, and improve the purity of the crystalline film formed, as compared with crystallization in atmosphere. For semiconductor films

and metallic films, it is well known that as the amounts
of the impurities in the film decreases, the physical
properties of the film such as mobility are improved. For
semiconductor films, impurities are intentionally added in
trace amounts of about 1×10^{18} cm^{-3} or less to control the
physical properties of the films. From this viewpoint
also, it is important to obtain a high-purity
semiconductor film. Contamination of the thin films from
air becomes more serious in melt crystallization than in
crystallization (solid phase crystallization: SPC) in a
solid state. This is because in a liquid state where the
processing temperature is higher than that in solid phase
crystallization, impurities diffuse and chemically react
with the components of the thin films at higher rates.
Therefore, control of the atmosphere in metal
crystallization has more important meaning than in solid
phase crystallization.

It is important from the viewpoints below that the
atmosphere for progressing metal crystallization contains
hydrogen. When a thin film is melted by supplying high
energy and then solidified to a crystal, the adjacent
atoms in the thin film combine with each other to form a
regular crystal structure. However, on the surface, no
bonding atom is present in the upper half thereof. Hence,

14

in melt crystallization under vacuum or in an inert gas, on the surface of the thin film, unpaired bonding electrons combine with each other to reconstruct the surface. The structure of the reconstructed surface is greatly different from the inner structure of the crystal, thereby causing a change in the band structure. In addition, large stress is present in the reconstructed surface. This stress affects as lattice distortion the crystal positioned in an under layer up to several periods thereof. A change in the band structure changes the concentrations of electrons and holes, and the lattice distortion decreases the mobilities of electrons and holes. In addition, bonding of atoms on the surface invariably produces unpaired bonding electrons. These electrons are chemically active and thus react with water and oxygen in air or absorb dust when the thin film is exposed to air at the end of crystallization of the thin film. In addition, the presence of unpaired bonding electrons produces interfacial levels and scattering centers of electrons and holes, thereby deteriorating mobilities of electrons and holes. Therefore, the reconstructed surface has various adverse effects on the physical properties of the thin films.

In the method of forming a crystalline film of the

present invention, melt crystallization of the thin film proceeds in an atmosphere containing hydrogen. Therefore, the unpaired bonding electrons of atoms which appear on the surface in the cooling solidification process are terminated by various types of hydrogen atoms (abbreviated to "hydrogen termination" hereinafter) contained in the atmosphere. The reconstruction of the surface is thus avoided, and at the same time, the total number of the unpaired bonding electrons is significantly decreased. Namely, the crystalline film obtained in accordance with the present invention has high purity and a surface structure extremely close to the inner crystal structure. As a result, the metallic surface simply reflects the intrinsic physical properties possessed by a metal itself, and the semiconductor surface also honestly exhibits the physical properties of the semiconductor. For example, when a FET (so-called TFT) comprising a polycrystal semiconductor thin film is formed according to the present invention, since mobility hardly deteriorates due to the reconstructed surface, the effective mobility is significantly improved, as compared with the effective mobility of a TFT formed by a conventional technique, and the value of mobility also does not change with substrates and lots.

In melt crystallization under an atmosphere of a mixed gas containing hydrogen molecules and an inert gas, no impurity is introduced into a crystallized film of a metal or semiconductor, and a high-purity crystallized film terminated with hydrogen is obtained. In melt crystallization of a semiconductor film of silicon or the like under a atmosphere containing a hydrogen halide and an inert gas, the crystallized semiconductor film is securely terminated with hydrogen on the basis of the fact that the halide relatively easily reacts with the semiconductor film. This is particularly effective to a metallic thin film. It is ideal to progress melt crystallization in an atmosphere of a mixed gas containing an inert gas and a gas containing a hydride of the component of the thin film. This is because hydrogen termination is securely performed, and high purity is guaranteed. Particularly, when the thin film comprises silicon, the best hydride is silane. Since silane rapidly reacts, it securely reacts with the unpaired bonding electrons which appear on the surface. This is because, as a result of reaction, even if silane is captured by the silicon thin film, only a silicon atomic layer is formed, without causing neither decrease in purity and nor lattice distortion.

In order to securely effect hydrogen termination in melt crystallization, the sufficient partial pressure of hydrogen or hydride in the atmosphere is about 10 mTorr or more. This is based on the following reasons. If the mass of one molecule of a gas is m (kg), the partial pressure is P (Pa), the temperature is T (K), the concentration is C (m^{-3}) and the average velocity is v ($m \cdot s^{-1}$), the flux density F ($m^{-2} \cdot s^{-1}$) of the gas is as follows:

$$F = \frac{1}{6} cv = \frac{1}{2} \frac{1}{\sqrt{3kTm}} \qquad \ldots (1) \text{ [Equation 1]}$$

wherein k is the Boltzmann's constant. If the melting time of recrytallization is indicated by τ (s), and the density of unpaired bonding electrons on the thin film surface is indicated by Nss (m^{-2}), in order to terminate all unpaired bonding electrons, it is a necessary condition that the number of gas molecules (flux density x melting time) which collide with the thin film surface within the melting time is larger than the density of unpaired bonding electrons. Namely, the following equation is established:

$$\tau F > Nss \qquad \ldots (2) \text{ [Equation 2]}$$

From Equations (1) and (2), the following equation is obtained for pressure:

18

$$P > \frac{2\sqrt{3kTm}}{\tau} \ Nss \qquad \ldots (3) \ \text{[Equation 3]}$$

When the partial pressure of hydrogen atoms or hydride satisfies Equation 3, a high quality surface can be obtained after melt crystallization. The possible shortest time of melt crystallization is generally 10 ns (τ = 1 x 10^{-8} s), and the maximum density of the unpaired bonding electrons, which is conceivable in a practical manner, is about 1 x 10^{12} cm^{-2} (Nss = 1 x 10^{16} m^{-2}). Therefore, if the partial pressure of hydrogen molecules or hydride is hither than the pressure calculated by using these values, Equation (3) is satisfied in melt crystallization of all thin films. The minimum partial pressure calculated for each hydride is as follows:

hydrogen molecule (H_2) PH_2 > 1 mTorr

hydrofluoric acid (HF)   PHF > 3 m Torr

hydrochloric acid (HCl)   PHCl > 4 mTorr

silane (SiH_4) $PSiH_4$ > 4 mTorr

nitric acid (HNO_3) $PHNO_3$ > 6 mTorr

sulfuric acid (H_2SO_4) PH_2SO_4 > 7 mTorr

Equation (3) indicates that the minimum partial pressure of a hydride increases as the molecular weight increases. However, the above results indicate that at

partial pressure of higher than about 10 mTorr, almost all materials satisfy the condition. The explosion lower limit concentration of hydrogen is about 4%, and the partial presser of hydrogen corresponding to this value is about 30 Torr. From the viewpoint of safety, the maximum partial pressure of hydrogen is said to be about 30 Torr. The explosion lower limit concentration of silane is about 1%, and the partial presser of silane corresponding to this value is about 7.6 Torr. From the viewpoint of safety, the other hydrides are preferably used at concentrations of about 1% or less, or partial pressure of about 7.6 Torr or less. With a margin for safety, the maximum partial pressure is said to be about 5 Torr. Eventually, for all hydrides (including hydrogen molecules), the partial pressure of melt crystallization for safely achieving the present invention is 10 mTorr to 5 Torr.

Although the partial pressure of hydride used in the second step has been described above, the total pressure is preferably atmospheric pressure or higher. Of course, melt crystallization under low pressure (vacuum) which satisfies the above partial pressure condition produces the same effect as described above. However, in a vacuum system apparatus, the cost is increased, and the process

is complicated. Melt crystallization under atmospheric pressure simplifies the apparatus and the process, thereby significantly improving productivity. Further, when processing in the second step is carried out under atmospheric pressure or higher, in metal crystallization, it is possible to significantly decrease evaporation and scattering of the component elements of the thin films and adhesion of the evaporated and scattered elements in the apparatus, as compared with processing under vacuum (referred to as "scattering suppression effect" hereinafter). This is caused by the fact that the melted surface is pressed by the gases which form the atmosphere, and evaporation and scattering are suppressed in proportion to pressure. Since the degree of this effect is determined by the level of total pressure, in principle, even if the pressure of only the hydrogen molecules or hydride used is increased to atmospheric pressure without using an inert gas, the same scattering suppression effect as the use of a mixed gas containing a hydride and an inert gas under atmospheric pressure can, of course, be obtained. However, it is very dangerous to handle such hydrides under atmospheric pressure. For this reason (guarantee for safety), a mixed gas containing hydrogen or hydride and an inert gas is preferable. As

21

the inert gas, nitrogen is most widely used and has the advantage of low price. When a metal or semiconductor is put into a high-temperature liquid state by supplying high energy, it reacts with nitrogen. However, rare gases have the advantage that they by no means react with any thin film materials even at high temperatures. Materials for thin films such as silicon and aluminum have relatively high atomic weights. Thus, of the rare gases, weight elements such as argon, krypton and xenon have the larger scattering suppressing effect. Since the abundances of krypton and xenon are low, and these elements are thus expensive. An inert gas which is inexpensive and practical and exhibits the large scattering suppression effect is argon.

(1-2. Form of a high energy supply apparatus and metal crystallization by the apparatus)

In order to stably progress the second step in which high energy is supplied to an object material such as the semiconductor thin film and metallic thin film formed on the substrate in the first step to melt and crystallize at least the surface layer, and in order to obtain a high-quality crystal, a high energy supply apparatus suitable for this purpose is required. In this chapter, forms of

22

the high energy supply apparatus are described by using light (laser beam) as an example of the forms of high energy with reference to Fig. 2. At the same time, the method of forming a crystalline film using the thin film formed on the substrate in the first step as the object material to which high energy is supplied in the second step will be discussed.

The high energy supply apparatus (Fig. 2) of the present invention comprises at least a generation source (laser emission source) 202 for generating high energy 207 such as a laser beam, and a supply chamber 201 in which the generated high energy is supplied to an object material (the substrate on which a thin film is formed). The supply chamber has a function (setting base) 205 for setting the object material 203 in the supply chamber. The setting base is provided with a movable function so that the high energy 207 can be supplied to a desired position of the object material. In a portion of the wall 209 of the supply chamber is provided an introduction window 206 for introducing high energy into the supply chamber, the introduction window comprising a material which less absorbs high energy and hardly transmits gas molecules. In other words, the introduction window is transparent to high energy and opaque to gas molecules.

23

For example, when the form of high energy is light, the
introduction window comprises transparent glass such as
quartz or the like.

In the present invention, the introduction window is
provided at a position where when high energy is supplied
to the object material (for example, a silicon thin film),
the component (in the case of a silicon thin film, silicon
atoms) of the object material hardly adhere to the
introduction window. For example, in the high energy
supply apparatus shown in Fig. 2, a portion of the wall of
the supply chamber is projected in a direction apart from
the object material, and the introduction window is
provided at the top of the projected portion 210. As a
result, the distance L1 between the introduction window
and the object material is larger than the shortest
distance L2 between the wall 209 and the object material.
In a state wherein the distance between the introduction
window and the thin film as the object material is larger
than the shortest distance between the wall and the thin
film, i.e., in a state wherein the introduction window is
provided at a position where the components of the thin
film hardly adhere to the introduction window even by
supplying high energy to the thin film, the high energy
207 is supplied to the thin film as the object material.

In Fig. 2, the scattering range of the elements evaporated and scattered from the object material as a result of supply of high energy (irradiation of a laser beam) is shown as the scattered component. In the present invention, since the introduction window is sufficiently separated from the object material, as compared with the scattering range of the object material, the components of the object material hardly adhere to the introduction window even if melt crystallization by supplying high energy is repeated. As described above, the introduction window must be transparent to high energy. Since the object material is opaque to high energy, high energy is converted into heat. If the object material adheres to the introduction window, the introduction window becomes opaque and thus does not have the function to fulfil. In the present invention, such an unreasonableness is rejected, and the high energy supply apparatus having excellent stability and productivity is realized.

When a crystallized film is obtained by irradiating the semiconductor thin film with a laser beam, it is particularly important to control the scattering range. Generally, the higher the energy supplied to the semiconductor thin film is, the more easily a good crystallized film is obtained. However, if the supplied

energy exceeds a certain upper limit, the semiconductor elements are explosively scattered, resulting in the absence of the semiconductor thin film or a decrease in the thickness thereof after supply of high energy. This is possibly caused by the fact that the semiconductor film comprises a covalent bond crystal and is hard, and has lower thermal conductivity than that of metals. Another possible cause is that since the semiconductor thin film is deposited by the vapor phase deposition process (CVD process) in the first step, the adhesion between the semiconductor film and the substrate or a surface protective film formed on the substrate is low. In either case, since the upper limit is present, the energy of the laser beam supplied for performing crystallization is set to as a high value as possible which is lower than the upper limit. However, the energy of the laser beam invariably changes, and the explosive scattering occurs in a statistical process. Therefore, in order to obtain a good crystalline semiconductor film, the scattering phenomenon cannot necessarily be ignored. From the above situation, it can be concluded that the high energy supply apparatus and the crystallized film forming method of the present invention in which the scattering range is controlled are particularly suitable for stably forming a

26

good crystalline semiconductor film on the substrate or the surface protective film with high productivity.

In order to decrease the size of the high energy supply apparatus itself and facilitate replacement of the atmosphere in the supply chamber, the unnecessary space in the supply chamber must be eliminated as much as possible. In consideration of setting and removal of the object material and vibration in operation of the setting base, the shortest distance between the wall and the object material is about 2 mm to 40 mm. On the other hand, the scattering range of the object material changes with pressure in the supply chamber. For example, the scattering range under a vacuum of about 10^{-5} Torr reaches about 10 cm or more, while the scattering range under atmospheric pressure is about 10 mm or less. Therefore, if melt crystallization is progressed under pressure of atmospheric pressure or higher, as described above in the previous chapter, the sufficient distance between the introduction window and the object material is about 20 mm or more. If high energy is supplied under pressure of about 10 mTorr or less, the distance is preferably at least about 50 mm, and ideally 100 mm or more. From these viewpoints, in order to comply with various pressures in the supply chamber, the distance is preferably about 50 mm

27

or more. Although there is no upper limit of this distance, if the upper limit is positively set, the upper limit is about 1000 mm. If the distance is too long, the volume of the supply chamber is increased, much time is required for replacing the atmosphere, and the size of the apparatus itself is also increased.

(1-3. Gas flows in the high energy supply apparatus and melt crystallization performed thereby)

In the previous chapter, the optimum form of the high energy supply apparatus has been described. In this chapter, gas flows in the supply chamber of the high energy supply apparatus will be described with reference to Fig. 3.

Fig. 3(A) shows the structure of the supply chamber of the high energy supply apparatus described in the previous chapter from the viewpoint of the gas flows, and Fig. 3(B) shows gas flows in the middle of crystallization of the object material performed by at least supplying high energy to the object material (the thin film formed on the substrate). The high energy supply apparatus of the present invention comprises pressure regulating means for generating a desired pressure distribution in the supply chamber 301, or gas flow regulating means for

generating desired gas flows in the supply chamber.
Specifically, the pressure regulating means or the gas
flow regulating means comprises at least an exhaust port
311 and a gas inflow port 312. The exhaust port is
provided at a portion of the wall 309 of the supply
chamber, for exhausting the air in the supply chamber. A
plurality of gas inflow ports (at the 6 positions shown in
Fig. 3(A)) are provided for flowing the various gases
described in detail in Chapter (1-1) in the supply
chamber. The amount of the gas flowing through each of
the gas inflow ports and the exhaust rate of the exhaust
port are appropriately adjusted to control the total
pressure and flows in the supply chamber by the pressure
regulating means and the gas flow regulating means.
Besides, the pressure regulating means and the gas flow
regulating means are capable of increasing the pressure in
the vicinity of the introduction window 306 to a value
higher than that in the vicinity of the object material,
and increasing the pressure in the vicinity of the object
material to a value higher than that in the vicinity of
the exhaust port. Therefore, in the second step, the high
energy 307 is supplied to the object material such as the
thin film set on the setting base 305 in the state wherein
the pressure in the vicinity of the introduction window is

higher than that in the vicinity of the object material,
or the pressure in the vicinity of the introduction window
is higher than that in the vicinity of the object material
(thin film) and the pressure in the vicinity of the object
material (thin film) is higher than that in the vicinity
of the exhaust port.

The gas flows in this state will be described with
reference to Fig. 3(B). First, the path of the high
energy which is introduced into the supply chamber 301
through the introduction window 306 and then applied to
the object material 303 is assumed in the supply chamber.
Part of the high energy which reaches the object material
through the irradiation passage enters the object
material, and another part thereof is scattered and
reflected from the object material. In this application,
the scattered reflected high energy is referred to as
"reflected energy 313". The path of the reflected energy
in the supply chamber is assumed as a reflection passage
314. As described above, the pressure distribution and
gas flows 320 regulated by the pressure regulating means
and the gas flow regulating means, respectively, are
present in the supply chamber. In the supply chamber of
the high energy supply apparatus of the present invention,
the gas flows can be controlled so that gases flow toward

the object- material from the introduction window in
substantially the same direction as the irradiation
passage, and flow from the object material in
substantially the same direction as the reflection
passage. This is caused by the fact that the pressure in
the vicinity 317 of the introduction window is higher than
that in the vicinity 318 of the object material, and the
pressure in the vicinity of the object material is higher
than that in the vicinity 319 of the exhaust port.
Eventually, high energy is supplied to the object material
such as the thin film to progress melt crystallization in
the state wherein the gases flow from the introduction
window in substantially the same direction as the
irradiation passage and flow from the object material in
substantially the same direction as the reflection
passage.

As described in the previous chapter, in melt
crystallization of a metal or semiconductor, the component
elements of the metal or semiconductor are invariably
evaporated. With supply of high energy, the component
elements are scattered as a fine powder. In the high
energy supply apparatus of the present invention, since
the gas flow from the introduction window side to the
object side is present, the probability that the

evaporated elements or scattered fine powder reach the
introduction window is significantly decreased. Since the
gas flow from the object material to the exhaust port in
substantially the same direction as the reflection passage
is also present, the evaporated elements or scattered fine
powder are exhausted through the gas flow. This fact not
only prevents adhesion to and contamination of the supply
chamber but also significantly restricts re-adhesion of
the evaporated elements or scattered fine powder to the
object material. Particularly, this has an important
meaning when a TFT or a super integrated circuit (LSI) is
manufactured by using the crystallized thin film formed on
the substrate. This is because the fine powder which
readheres to the thin film causes deterioration in
precision of fine processing and electrical short circuit.
Since the fine powder is chemically active and has high
reactivity to the wall of the supply chamber, the fine
powder possibly re-adheres to the object material such as
the thin film after such chemical reaction, thereby
deteriorating the purity of the thin film itself. The
high energy supply apparatus and the crystalline film
forming method of the present invention can completely
remove these adverse effects, and stably produce a good
crystal.

(1-4. Utilization of reflected energy)

In this chapter, the high energy supply apparatus of the present invention described in detail in Chapter (1-2) is further improved, and a method of forming a crystalline film using the apparatus will be described.

Fig. 4 shows the structure of a supply chamber 401 of the high energy supply apparatus of the present invention. As described in Chapter (1-2), the high energy supply apparatus comprises at least a generation source (omitted in Fig. 4) for generating high energy 407 and a supply chamber for supplying high energy to an object material 403 (a metallic thin film or a semiconductor thin film). In the supply chamber is provided setting means 405 having the function to set the object material in the chamber, the object material such as a substrate having a thin film formed in the first step being set on the setting means. In a portion of the wall 409 of the supply chamber is provided an introduction window for introducing high energy into the supply chamber so that the positional relationship between the introduction window 406 and the object material satisfies the conditions described in Chapter (1-2). In the supply chamber are provided pressure regulating means and gas flow regulating means comprising an exhaust port 411 and gas inflow ports 312,

respectively, so that the pressure distribution and gas flows described in Chapter (1-3) are present in the supply chamber. Of course, the atmosphere in the supply chamber is set according to the description in Chapter (1-1). The path of the high energy introduced into the supply chamber through the introduction window and then applied to the object material is assumed as the irradiation passage.

In the high energy supply apparatus of the present invention, the introduction window or the setting means is disposed so that the direction of the normal line of the object material such as the thin film is shifted from the direction of the irradiation passage 415. Therefore, in crystallization of the thin film, high energy is supplied to the thin film in the state wherein the normal direction of the normal line of the thin film is deviated from the direction of the irradiation passage. In the high energy supply apparatus of the present invention, an exhaust port is also provided in the normal direction of the object material such as the thin film. Such a configuration permits an increase in the distance between the introduction window and the object material in the small supply chamber, and easily produces the same construction and effect described in Chapter (1-2). In addition, since the exhaust port is provided at a position at the shortest

distance between the object material and the wall of the supply chamber, the evaporated elements and scattered fine powder are effectively discharged. Further, since the rate of discharge of the evaporated elements and scattered fine powder in the normal direction of the normal line is particularly high, the efficiency of discharge is improved, and the effect described in Chapter (1-3) is securely attained.

The high energy supply apparatus of the present invention further comprises means for changing the course of reflected energy so that the object material is irradiated again with the reflected energy 413. The course changing means 418 further comprises positioning means for permitting a desired position of the object material such as the thin film to be irradiated with the reflected energy. After the thin film formed on the substrate in the first step is set in the supply chamber, a first position of the thin film is irradiated with high energy. Part of the high energy enters the thin film, and another part is reflected from the thin film to generate reflected energy. The course of the reflected energy is changed by the course changing means so that a second position of the thin film is again irradiated to progress melt crystallization. If the high energy has a high

velocity, as light, irradiation of the second position is generally started with the reflected energy corresponding to the high energy for irradiating the first position of the thin film during the time of irradiation of the first position of the thin film with the high energy. The first position and the second position are adjusted by the positioning means. If the high energy is light, the course changing means comprises an optical device such as a mirror, a lens or a prism. If the high energy is charged particles, the course changing means comprises an electromagnetic generator. The positioning function is the function to change the positional relation (for example, the angle of the mirror) of an optical device, or finely adjust an electromagnetic field.

Fig. 5 shows an example of the simplest apparatus using light as high energy. Reference numeral 506 denotes an introduction window; reference numeral 511, an exhaust port; reference numeral 512, a gas inflow port; and reference numeral 516, a normal line. In this example, course changing means 518 comprises a mirror, preferably converging means such as a concave mirror or the like. Although reflected light generally contains scattered components, the converging means converges scattered light to permit efficient re-irradiation. Incident light is

36

applied to the object material 305 such as the thin film and is then partially reflected to generate reflected light. The reflected light is converged and reflected by the concave mirror, and then applied to the object material again. This can significantly increase the efficiency of utilization of the high energy 507. For example, reflectance of ultraviolet light and visible light by a semiconductor thin film reaches about 70% or more, and the reflectance by a metal thin film is about 90% or more. Although a convention efficiency of energy utilization is about 10% to 30%, the present invention can substantially double the efficiency of energy utilization from about 20% to 50% because the reflected energy 513 is efficiency re-utilized. This is particularly remarkable when the irradiation position (first position) where the object material is irradiated with high energy is substantially the same as the irradiation position (second position) where the object material is irradiated with the reflected energy. In Fig. 6, this effect is described with reference to an example in which a laser beam is emitted as pulses. In Fig. 6, the time at the non-irradiation point of the object material is shown on the abscissa, and irradiation is started at t = 0. The intensity of energy (arbitrary unit) which actually enters

37

the object material to contribute to melt crystallization
is shown on the ordinate. When irradiation is started,
the energy intensity of the high energy is increased to
the maximum at $t = t_1$. The reflected energy is applied to
the object material with a slight delay corresponding to
the distance between the object material and the course
changing means and the velocity. It is assumed that the
time the energy density of the reflected energy is the
maximum is t_2, the delay is indicated by $t_2 - t_1$. In this
way, the energy density of the incident high energy is
superimposed on the energy density of the reflected
energy. In this application, this total of energy density
actually contributes to melt crystallization. Fig. 6
shows this effect as synthetic light. As described above,
the present invention can substantially double the
conventional efficiency of energy utilization.

In the further improved high energy supply apparatus
of the present invention, the course changing means has
the function to adjusting time. This function is to delay
the time (shown by $t2 - t_1$ in Fig. 6) of re-irradiation of
the object material with the reflected energy. (In this
application, the delay is referred to as "the delay time"
hereinafter). For example, the time regulating means 419
can be composed of a plurality of reflecting means which

can reflect the high energy. Fig. 4 shows a simple
example of this means. If the high energy is light, the
reflecting means is composed of combination of mirrors.
The time-regulating means is means for changing the length
of the course of the reflected energy or changing the
velocity of the reflected energy. The former means is
useful when the high energy is light, and the latter means
is useful when the high energy is charged particles. This
is because the course length of light can be changed by
changing combination of mirrors, and the velocity of
charged particles can be changed by adjusting an electric
field. The irradiation time of the object material with
high energy can be increased by appropriately adjusting
the delay time. This will be described below with
reference to Fig. 7. In Fig. 7, the same things as those
shown in Fig. 6 are respectively shown on the abscissa and
the ordinate. In Fig. 7, the delay time $(t_2 - t_1)$ is
substantially the same as the emission time width (the
half width of incident light shown by t_a in Fig. 7) of the
high energy. As a result, the half width of the synthetic
light is substantially doubled (shown by t_b in Fig. 7).

An increase in the time half width of the high energy
means that energy is rapidly supplied to the object
material, and the probability of occurrence of the

explosive scattering can significantly be decreased. For

example, the hydrogenated amorphous silicon film (a-Si:H)

formed by a plasma chemical vapor phase deposition process

(PECVD process) is used as the object material, and the

object material is crystallized by irradiation with a

xenon·chlorine (XeCl) excimer laser (abbreviated to a XeCl

laser with a wavelength of 308 nm) as high energy. This

thin film generally has a high hydrogen content and a low

density, and is thus very difficult to melt crystallize.

In fact, an amorphous film is not at all crystallized by a

XeCl laser having a time half width of about 50 ns with an

irradiation energy density of about 100 $mJ \cdot cm^{-2}$ or less.

Conversely, if the energy density exceeds this value,

explosive scattering occurs. Eventually, the thin film is

not crystallized over the entire energy region. On the

other hand, the amorphous thin film is not crystallized by

a XeCl laser having a time half width of about 100 ns with

an irradiation energy density of about 100 $mJ \cdot cm^{-2}$ or less,

while with an energy density between about 100 $mJ \cdot cm^{-2}$ to

150 $mJ \cdot cm^{-2}$, melt crystallization completely proceeds.

Although, with an energy density of about 150 $mJ \cdot cm^{-2}$ or

more, the explosive scattering occurs as described above,

the energy density range which enables melt

crystallization is widened by further increasing the time

half width. Even with the same energy density of 125 $mJ \cdot cm^{-2}$, high energy having a short time half width (50 ns) and high energy having a long time half width (100 ns) have different effects on the object material. This difference is based on a difference in the energy transfer per unit time. With a long time half width, the amount of the energy transferred from high energy to the object material per unit time is decreased, thereby suppressing the explosive scattering. This is the same as a difference between combustion and explosion of an explosive. Explosion means the phenomenon which occurs when the energy transfer per unit time is large. For this reasons, in melt crystallization of an amorphous semiconductor film formed by PECVD or sputtering process at a relative low temperature (the substrate temperature is about 400°C or less) by supplying high energy, the time half width of the high energy is preferably about 100 ns or more. As described above, in the present invention, it is possible to simply increase the time half width, and crystallize the thin film which was conventionally considered as difficult to melt crystallize.

(1-5. Method of manufacturing thin film electronic device)
    The high energy supply apparatus described in detail

in the above chapters, and the crystalline film formed by using the apparatus can be applied to various thin film electronic devices such as semiconductor devices such as TFTs and LSIs, metal-insulator-metal elements (MIM elements), solar cells, printed boards, etc., and the performance thereof can significantly be improved. In this chapter, the method of manufacturing an excellent thin film electronic device with reference to a TFT with highest applicability as an example.

Figs. 8(a) to (d) are schematic sectional views showing the steps of manufacturing a thin film semiconductor device (so-called TFT) which constitutes a MIS type field effect transistor. The method of manufacturing a TFT in accordance with the present invention will be briefly described.

The present invention uses general purpose non-alkali glass as an example of the substrate. On a substrate 801 is formed a surface protective film 802 comprising an insulator by an atmospheric pressure chemical vapor deposition process (APCVD process), the PECVD process or the sputtering process or the like. A semiconductor film such as an intrinsic silicon film serving as an active layer of a thin film semiconductor device is then deposited (a first step for the semiconductor film). The

42

semiconductor film is formed by a chemical vapor
deposition process (CVD process) such as PECVD, APCVD or
LPCVD or a physical vapor phase deposition process (PVD
process) such as sputtering or vapor deposition. The
thus-obtained semiconductor film is supplied with high
energy such as a laser beam as a representative to
progress melt crystallization (a second step for the
semiconductor film). If the thin film deposited in the
first step is amorphous or a mixed crystal containing an
amorphous material and a fine crystal, this second step is
generally called "the crystallization step" On the other
hand, if the thin film deposited in the first step is
polycrystalline, this step is called the recrystallization
step. In the specification of this application, no
distinction is made between both cases, and this step is
simply called the crystallization step. Both cases
correspond to the melt crystallization of this application
as long as at least the surface of the thin film is melt
crystallized by supplying high energy. Melt
crystallization is an extremity excellent technique from
the viewpoint that a high quality crystalline thin film
can be formed on a large substrate with high productivity.
In melt crystallization by supplying high energy, the
energy supply time (with a laser beam, the irradiation

43

time) is generally as short as about 10 ns to 500 ns, and the energy supply region (laser irradiation region) is localized on the entire substrate. Thus, in crystallization, the entire substrate is not simultaneously heated to a high temperature, thereby causing no deformation and crack due to the heat of the substrate, After the crystalline semiconductor film (polycrystalline silicon film) is formed according to the crystalline film forming method described in detail above, the crystalline semiconductor film is processed to an island form, and an active semiconductor film 803 serving as an active layer of a transistor is formed (Fig. 8(a)).

After the active semiconductor film is formed, a gate insulating film 804 is formed by CVD or PVD (Fig. 8(b)).

A metallic thin film serving as a gate electrode 805 is then deposited by PVD or CVD. Since the gate electrode and gate wiring are generally formed by using the same material in the same step, the material used must have low electric resistance and resist the highest temperature (in this example, about 350°C) and chemicals in the subsequent steps for manufacturing the thin film electronic device. Thus, a tantalum (Ta) film having such properties is formed by sputtering (a first step for the metal). The tantalum thin film formed by sputtering generally has a β-

structure and resistivity of as high as about 200 $\mu\Omega$cm. The tantalum thin film also has internal stress and is apt to cause disconnection when used for wiring. In the present invention, therefore, high energy is supplied to the tantalum thin film (a second step for the metal) to improve the quality of the thin film. When melt crystallization of the tantalum metallic thin film is progressed by the method described in detail in the previous chapters, the crystallized film comprises α-structure tantalum (Ta). The α-structure tantalum has a cubic crystal system and a body-centered cubic crystal structure (bcc). The α-structure tantalum also has a resistivity of about 20 $\mu\Omega$cm to about 60 $\mu\Omega$cm and low internal stress. The α-structure tantalum is extremely excellent as a wiring material, as compared with the above β-structure tantalum.

After the metallic thin film serving as the gate electrode and gate wiring is formed, shaping is carried out. Then, impurity ions are injected into the active semiconductor film to source-drain regions and a channel formation region 806, 807 and 808 (Fig. 8(c)). At this time, since the gate electrode is used as a mask for ion injection, the channel formation region is formed only under the gate electrode in a self alignment manner. In

45

order to inject impurity ions, two types including an ion doping method for injecting hydride and hydrogen as impurity elements to be injected by using a mass non-separation ion injection apparatus, and an ion implantation method for injecting only a desired impurity element by using a mass separation type ion injection apparatus can be used. When CMOS TFT is formed, an appropriate mask material such as polyimide resin or the like is used, and NMOS and PMOS are alternately masked to inject each ion by using one of the above methods.

Then, a layer insulating film 809 is formed by CVD or PVD. After ion injection and formation of the layer insulating film, heat treatment is carried out for several tens minutes to several hours in an appropriate heat environment of about 350°C or less to activate the injected ions and thermally shrink the layer insulating film. After the layer insulating film is formed, contact holes are formed above the source and drain, and a source-drain lead-out electrode 810 and wiring 811 are formed. At this time, the melt crystallization of the metallic thin film described in the previous chapters may be applied to the metal which constitute the source-drain electrodes and wiring, as the gate electrode and gate wiring. After the crystalline metallic film is formed,

the thin film is processed to electrodes and wiring to complete a thin film semiconductor device (Fig. 8(d)).

(2-1. Substrate and surface protective film to which the present invention is applied)

In this chapter, the substrate and the surface protective film to which the present invention is applied will be described. As the substrate to which the present invention can be applied, conductive materials such as metals, ceramic materials such as silicon carbide (SiC), alumina (Al_2O_3), aluminum nitride (AlN), and the like; transparent insulating materials such as fused quartz, glass and the like; semiconductor substrates such as silicon wafers; and crystalline insulating materials such as LSI obtained by processing semiconductor substrates, sapphire (trigonal system Al_2O_3 crystal), and the like can be used. As an low-price general purpose glass substrate, #7059 glass or #1737 glass produced by Corning Japan Co., Ltd. or OA-2 glass produced by Nippon Denki Glass Co., ltd., NA35 glass produced by NH Technoglass Co., Ltd. and the like can be used. When a thin film semiconductor device is manufactured by using a crystalline semiconductor thin film, or when metallic wiring is formed by using a crystalline metallic thin film, at least a part

47

of the substrate comprises an insulating material, and the crystalline thin film is formed on the insulating material regardless of the type of the substrate used. In this application, the insulating material film is referred to as "the surface protective film". For example, when a fused quartz substrate is used, since the substrate itself comprises an insulating material, a crystalline film may be formed directly on the fused quartz substrate. Alternatively, the crystalline thin film may be formed after an insulating material such as a silicon oxide film (SiO_x: $0 < x \leq 2$) or a silicon nitride film (Si_3N_x: $0 < x \leq 4$) is formed as the surface protective film on the fused quartz substrate. When a glass plate is used as the substrate, generally, a crystalline film such as a semiconductor film may be formed directly on the glass substrate comprising an insulating material. However, in order to prevent contamination of the thin film with movable ions such as sodium (Na) contained in glass, the crystalline film is preferably formed after the surface protective film is formed on the glass substrate by using an insulating material such as silicon oxide or silicon nitride. The thin film electronic device such as the thin film semiconductor device manufactured as described above causes no variation in operational characteristics in use

for a long time or under a high voltage, thereby improving stability. In the case of the crystalline semiconductor film, the thin film is preferably formed on the surface protective film except the case where a crystalline insulating material such as sapphire is used as the substrate. When any one of various ceramic substrates is used as the substrate, the surface protective film is preferably provided for preventing a sintering auxiliary material added to ceramic from diffusing into the thin film and contaminating it. When a metallic material is used as the substrate, the surface protective film is necessary and essential to secure insulating properties. In addition, in a semiconductor substrate and LSI device, the layer insulating film or the like provided between transistors or wiring layers plays a part as the surface protective film. The size and shape of the substrate are not at all limited as long as no deformation such as shrinkage, distortion or the like occurs in the heat environment of the manufacturing process. Namely, any desired substrate including a disk having a diameter of 3 inches *76.2 mm) and a rectangular substrate of about 600 mm x 800 mm or more can be used.

(2-2. Thin films to which the present invention can be

applied, and gases containing the components thereof)

In this chapter, the thin films to which the present invention is applied, and gases containing the component elements of semiconductor films among the gases which constitute the atmosphere described in Chapter (1-1) will be described.

In the present invention, any kinds of crystalline materials can be used as the object material. For example, the present invention can be applied to melt crystallization of diamond or the like. However, when a semiconductor thin film or a metallic thin film is selected as the object material, the advantageous effect of the present invention is most simply securely exhibited. The present invention can be applied to all types of metals. Particularly, the present invention is effective for materials such as tantalum described in Chapter (1-5) wherein the crystal phase is changed by supplying high energy or melt crystallization. Other metals in which the crystal grain size is increased as a result of metal crystallization are also preferred. Semiconductor thin films are most suitable for application of the present invention. Because the semiconductor thin film formed in the first step is amorphous or crystalline with low quality, but such a low quality thin film is

easily improved to an excellent crystalline thin film by carrying out the second step of the present invention.

The types of semiconductor films to which the present invention can be applied include single semiconductor films of silicon (Si), germanium (Ge) and the like; semiconductor films of Group IV element composite materials such as silicon·germanium (Si_xGe_{1-x}: $0 < x < 1$), silicon·carbide (Si_xC_{1-x}: $0 < x < 1$), germanium·carbide (Ge_xC_{1-x}: $0 < x < 1$), and the like; semiconductor thin films of composite compounds of Group III elements and Group V elements such as gallium·arsenic (GaAs), indium·antimony (InSb), and the like; thin films of composite compounds of Group II elements and Group VI elements such as cadmium·selenium (CdSe), and the like. The present invention can also be applied to semiconductor thin films of composite compounds such as silicon·germanium·gallium·arsenic (SixGeyGazAsz: $x + y + z = 1$), N type semiconductor films obtained by adding a donor element such as phosphorus (P), arsenic (As), antimony (Sb) or the like to these semiconductor films, and P-type semiconductor films obtained by adding an acceptor element such as boron (B), aluminum (Al), gallium (Ga), indium (In) or the like to these semiconductor films.

51

When the semiconductor film comprises silicon (Si),
gases containing the component element of the
semiconductor film include silanes such as monosilane
(SiH_4), disilane (Si_2H_6), trisilane (Si_3H_8), dichlorosilane
(SiH_2Cl_2), and the like. When the semiconductor film
comprises germanium, germane (GeH_4) is used. When the
semiconductor film comprises phosphorus (P) or boron (B),
or when such an element is added to an intrinsic
semiconductor film, phosphine (PH_3), diborane (B_2H_6) and
the like can also be used. Although chemical materials
containing the elements which constitute the above various
semiconductor films are used as gases for forming the
atmosphere, since these gases necessarily partially remain
in the semiconductor films, hydrides of the component
elements are preferably used. For example, chlorine (Cl)
variably remains in a silicon film formed by using
dichlorosilane (SiH_2Cl_2) regardless of the amount of
chlorine, and thus residual chlorine causes deterioration
in transistor characteristics when the silicon film is
used for the active layer of a thin film semiconductor
device. Therefore, monosilane (SiH_4) which is a hydride of
the component element is preferred, as compared with
dichlorisilane.

(2-3. Laser beam as high energy)

In this chapter, types of light when a laser beam is used as high energy will be described. The laser beam used in the present invention is not limited, and various light sources are used according to the object material used. A KrF excimer laser (wavelength 248 nm) and a XeCl excimer laser (wavelength 308 nm) are widely used in the industrial field because of stable emission of light. Besides, a ArF excimer laser and a XeF excimer laser (wavelength 351 nm) can also be used as the excimer layer. A YAG laser, a carbon dioxide laser, a Ar main beam laser (wavelength 514.5 nm), a Ar sub-beam laser (wavelength 448 nm), a HeNe laser (wavelength 632.8 nm), a HeCd laser (wavelength 441.6 nm), and other various pigment lasers can also be used. When the object material is a semiconductor film comprising silicon as a main component, XeF laser, the Ar main beam laser, Ar sub-beam laser, HeNe laser, and HeCd laser exhibit higher absorption coefficients in the amorphous component than that in the crystalline component. This means that in a system containing an amorphous component and a crystalline component, energy absorption of the amorphous component is higher than that of the crystalline component, and the temperature of the amorphous component easily rises.

Namely, crystallization of the amorphous component more easily takes place than recrystallization of the crystalline component. As described above, in melt crystallization of the semiconductor film, as the energy supplied increases within the range which causes no damage to the semiconductor film, the quality of the crystallized film obtained is improved. If the temperature of the crystalline component more easily rises, the semiconductor film is damaged before the amorphous component is completely crystallized. In other words, the film is damaged before recrystallization is completed. The XeF laser or the like does not causes such a trouble, and can thus be said to be very suitable for melt crystallization of a silicon semiconductor film. It is thus important to select the high energy source so that the absorption coefficient of the object material before supply of high energy is higher than that of the crystalline object material after supply of high energy.

Since the KrF laser and XeC laser exhibit high absorption coefficients in a semiconductor film comprising silicon as a main component, these lasers are suitable for crystallization of thin films having a thickness of about 50 nm or less. The absorption coefficients of the XeF laser and HeCd laser are slightly lower than those of the

KrF laser and XeCl laser, and thus the XeF laser and HeCd laser are suitable for crystallizing silicon semiconductor thin films having a thickness of about 50 nm to 1000 nm. Since the absorption coefficients of Ar main beam laser and Ar sub-beam layer and HeNe laser in semiconductor films are low, they are suitable for crystallizing semiconductor thin films having a thickness of about 1000 nm or more.

As described above, the present invention enables simple stable melt crystallization of the object material by supplying high energy thereto, and easy formation of high-quality crystalline films. Such crystalline thin films permit manufacture of excellent thin film electronic devices. Specifically, the present invention has the following effects:

Effect 1) Since crystallization is progressed under control of an atmosphere which can easily safely be replaced, no impurity such as oxygen, nitrogen or dust is captured by the crystalline thin film. Particularly, when the crystalline film comprises a semiconductor or metal, high purity and high quality crystalline film can be obtained.

Effect 2) It is possible to supply high energy under atmospheric pressure, and thus simplify the high energy

supply apparatus. This decreases the cost of a thin film electronic device comprising the crystalline film, and increases productivity.

Effect 3) In melt crystallization, the component elements of the object material are necessarily scattered or evaporated from the melted object material. It is possible to protect the incident window from evaporation, and thus keep the high energy supplied to the object material constant. A crystalline film having good characteristics can thus be obtained, and the quality of the film is significantly stabilized.

Effect 4) In progress of melt crystallization by supplying high energy such as laser irradiation to the object material, as the energy supplied increases, the quality of the resultant crystal is generally improved. In this application, since high energy can be applied under atmospheric pressure, even if the supplied energy is increased, the phenomenon such as scattering or evaporation can be suppressed, thereby improving the quality of the crystalline film.

Effect 5) Control of the surface plays an important role in obtaining a good crystalline film. In the crystallization method of the present invention, the control of the surface is sufficiently achieved, and thus

an excellent crystalline film can be obtained. Further,
since the recrystallized surface is controlled to the same
state in each time of melt crystallization, the film
characteristics of the crystalline film are significantly
stabilized.

Effect 6) The efficiency of use of high energy can be
substantially doubled. In addition, the time half width
can be increased, and a material which cannot be
crystallized by a conventional process can be
crystallized.

Brief Description of the Drawings
Fig. 1 is a drawing showing a conventional laser
irradiation apparatus. Fig. 2 is a drawing showing a high
energy supply apparatus of the present invention. Fig. 3
is a drawing showing a high energy supply apparatus of the
present invention. Fig. 4 is a drawing showing a high
energy supply apparatus of the present invention. Fig. 5
is a drawing showing a high energy supply apparatus of the
present invention. Fig. 6 is a drawing showing changes in
the high energy supplied to an object material with time.
Fig. 7 is a drawing showing changes in the high energy
supplied to an object material with time. Figs. 8(a) to
(d) are sectional views showing a device in the respective

57

steps for manufacturing a thin film semiconductor device in accordance with an embodiment of the present invention. Fig. 9 is a drawing showing the configuration of a transmission type liquid crystal display device according to the present invention. Fig. 10 is a drawing showing the configuration of an electronic apparatus according to the present invention. Fig. 11 is a drawing showing an example (liquid crystal projector) of electronic apparatus according to the present invention. Fig. 12 is a drawing showing another example (personal computer) of electronic apparatus according to the present invention. Fig. 13 is a drawing showing a further example (pager) of electronic apparatus according to the present invention.

Best Mode for Carrying out the Invention

The present invention will be in further detail below with reference to the drawings.

(Embodiment 1)

A surface protective film comprising a silicon oxide film is formed on a large glass substrate of 360 mm x 475 mm x 1.1 mm by the PECVD process, and an intrinsic silicon film is then formed on the surface protective film without breakage of vacuum (the first step for silicon). The thickness of the surface protective film is 300 nm, and

the thickness of the semiconductor film is 60 nm. The glass substrate in equilibrium with room temperature is set in an PECVD apparatus in which a lower plate electrode is kept at a temperature of 380°C. Conditions for depositing the silicon film are as follows:

Time: t = 164 s

Flow rate of silane: SiH_4 = 100 SCCM

Flow rate of argon : Ar = 3000 SCCM (raw material concentration 3.23%)

Power of radio frequency: RF = 600 W (0.228 W/cm^2)

Pressure: P = 1.5 Torr

Electrode distance: S = 37.1 mm

Temperature of the under plate electrode: Tsus = 380°C

Temperature of the substrate surface: Tsub = 349°C The deposition rate of the semiconductor film under these conditions was 0.365 nm/s, and the thickness of the semiconductor film was 60 nm. The hydrogen concentration of the silicon film which was measured by thermal desorption gas spectroscopy (TDS) was 10.39 atomic %. Observation by a transmission electron microscope indicates that the silicon film mainly comprises a mixed crystal containing a prismatic structure amorphous component. The results of Raman spectroscopic measurement

of the silicon film show a Raman shift at about 520 cm^{-1}, and thus indicates that the silicon film of the present invention comprises a mixed crystal.

The thus-obtained silicon film was irradiated with a laser beam to progress melt crystallization (the second step for silicon). Melt crystallization is carried out by a high energy supply apparatus having the laser irradiation chamber (supply chamber) shown in Fig. 4. The laser beam is irradiated by using a KrF excimer laser having a wavelength of 248 nm and a half width of about 33 ns. Since reflected light is applied again with a delay time of about 30 ns by the time regulating means, the substantial time half width is about 60 ns. The time regulating means comprises a combination of mirrors, and the total length of the optical path of the reflected light is about 9 m. Incident light is applied at an angle of 60° with respect to the normal line. Since the shortest distance between the thin film and the wall of the supply chamber is 20 nm, the distance between the introduction window and the irradiation position on the thin film is generally 40 nm. The laser beam has a linear shape having a width of 120 μm and a length of 38 cm. The widthwise overlap of the beams applied in respective irradiations is 90% of the width of a beam. Therefore, a

beam advances by 12 μm in each irradiation, and the same point on the semiconductor thin film is irradiated with a laser beam ten times. The energy density of the laser beam is 150 mJ·cm^{-2}. Irradiation of the laser beam is performed under atmospheric pressure. Mixed gases containing argon and monosilane are introduced into the supply chamber at a rate of 1 slm through the gas inflow port, and discharged through the exhaust port provided on the normal line of the thin film. The gases flow from the introduction window and the course changing means (including the positioning function and the time regulating means) to the irradiation position, and further flow from the irradiation position toward the exhaust port. Since the silane concentration of argon is generally 100 ppm, the partial pressure of silane is generally about 76 mTorr in irradiation with the laser beam. In irradiation with the laser beam, the substrate temperature is room temperature of about 25°C. The degree of crystallization of the thus-crystallized semiconductor film which was measured by multiwavelength dispersion type epsometory was 98%, and the thickness thereof was 55 nm. Raman spectroscopic measurement shows a sharp peak with a half width of 4.4 cm^{-1} at about 515 cm^{-1} which indicates a Raman shift caused by the crystalline component. This

61

indicates that a high quality film having high crystallinity is formed. After the crystallization step, this crystalline film is patterned, and an active layer semiconductor film serving as an active layer of a transistor is then formed.

A gate insulating film is then formed by PECVD. The gate insulating film comprising a silicon oxide film is deposited to a thickness of 100 nm at a substrate surface temperature of 350°C by using TEOS $(Si-(O-CH_2-CH_3))_4)$, oxygen (O_2) and water (H_2O) as raw material gases and argon as a dilution gas. After the gate insulating film is formed, the oxide film is heat-treated in an atmosphere containing oxygen at a partial pressure of about 0.2 atm and water vapor with a dew point of about 80°C at a temperature of about 350°C for about 3 hours to improve the quality of the insulating film.

A tantalum (Ta) thin film serving as a gate electrode is then deposited by sputtering (the first step for tantalum). In sputtering, the substrate temperature is 150°C, and the thickness of the film is 500 nm. The thus-obtained tantalum film is then irradiated with a laser (the second step for tantalum). Conditions for laser irradiation are the same as the conditions for crystallization of the semiconductor film except that the

atmosphere gas is changed to mixed gases containing argon and hydrogen. Since the hydrogen concentration of argon is about 1%, the partial pressure of hydrogen in laser irradiation is generally 7.6 Torr. The tantalum film after laser irradiation has the α structure, as described above, and a resistivity of about 40 $\mu\Omega$cm. After the tantalum thin film as the gate electrode is formed, pattering is performed.

An impurity ion is then injected into the semiconductor film to form source-drain regions and a channel region. At this time, the gate electrode served as a mask for injection, and the channel is formed only under the gate electrode in the self alignment manner. In this example TFT having a CMOS structure is formed. The PMOS TFT portion is covered with a polyimide resin in formation of NMOS TFT source-drain, and conversely the NMOS TFT portion is covered with a polyimide resin in formation of PMOS TFT source-drain to form the CMOS TFT. An impurity ion is injected by using a mass non-separation type ion injection apparatus, and about 5% of phosphine (PH_3) diluted with hydrogen is used as a raw material gas for HMOS. The total of the ions including PH^{3+} and H_2^+ implanted is 1×10^{16} cm^{-2}, and the concentration of phosphorus atoms in the source-drain regions is about 3 x

10^{20} cm^{-2}. In ion injection, the substrate temperature is 250°C. For PMOS TFT, about 5% of diborane (B$_2$H$_6$) diluted with hydrogen is used as a raw material gas. The total of the ions including B$_2$H$_6^+$ and H$_2^+$ implanted is 1 x 10^{16} cm^{-2}, and the concentration of boron atoms in the source-drain regions is about 3 x 10^{20} cm^{-2}. In ion injection, the substrate temperature is also 250°C.

A layer insulating film comprising a silicon oxide film is then formed by the PECVD process using TEOS. In deposition of the layer insulating film, the surface temperature of the substrate is 350°C, and the thickness of the film is 500 nm. Then heat treatment is performed at 350°C in an oxygen atmosphere for 1 hour to activate the injected ions and thermally shrink the layer insulating film. Contact holes are the formed on the source-drain, and aluminum (Al) is deposited by sputtering. In sputtering, the substrate temperature is 150°C, and the thickness of the Al film is 500 nm. The aluminum thin film for forming a source-drain lead out electrode and wiring is patterned to complete a thin film semiconductor device.

The transistor characteristics of the thin film semiconductor device formed on an experimental base were measured. The source-drain current Ids when the

transistor is turned on at a source-drain voltage Vds of ±4 V and a gate voltage Vgs of ±10 V is defined as an on current ION (+ and - signs of voltage indicate the measurement conditions of NMOS and PMOS, respectively). The source-drain current Ids when the transistor is turned off at Vds of ±4 V and Vgs of 0 V is defined as an off current. Measurement was carried out for a transistor in a channel formation region having a length L of 5 μm and a width W of 5 μm at a temperature of 25°C. Mobility and threshold voltage were calculated from the saturation current. In this embodiment, in order to examine the performance of the transistor and variations in the substrate thereof, measurement was made for 50 transistors uniformly formed on a large glass substrate. The results obtained are as follows:

NMOS TFT

ION = (74.3 + 9.0, -6.8) x 10^{-6} A

IOFF = (1.38 + 0.53, -0.37) x 10^{-12} A

μ = 124.1 ± 12.6 $cm^2 \cdot V^{-1} \cdot S^{-1}$

Vth = 2.13 ± 0.13 V

PMOS TFT

ION = (51.6 + 4.7, -4.1) x 10^{-6} A

IOFF = (3.87 + 0.99, -0.80) x 10^{-13} A

μ = 69.3 ± 6.04 $cm^2 \cdot V^{-1} \cdot S^{-1}$

Vth ≒ -1.11 ± 0.11 V

Therefore, the present invention is capable of
uniformly manufacturing a excellent CMOS thin film
semiconductor device with high mobility on a large
general-purpose glass substrate at the highest temperature
(350°C) of the process as the same as a conventional a-Si
TFT. Since the TFT obtained in this example comprises the
good crystalline semiconductor film and gate electrode,
the reliability as a transistor is extremely high, and the
operation is stable over a long period of time. In a
conventional low-temperature process, uniformity of laser
crystallization is a very important problem regardless of
the substrates and lots. However, the present invention
can significantly decrease variations in the on-current
and off-current. This significant improvement in
uniformity means that the crystalline silicon film of the
present invention has excellent properties, and
crystallization is stably progressed by the laser
irradiation apparatus (high energy supply apparatus) used.
In addition, since the tantalum film has low stress and
low resistivity, when the thin film semiconductor device
of the present invention is applied to LCD, uniform image
quality can be obtained over the entire LCD screen.
Further, when a circuit is formed by using the thin film

semiconductor device of the present invention, not only simple circuits such as a shift register and an analog switch but also complicated circuits such as a level shifter, a digital analog converter circuit, a clock generator circuit, a γ- correction circuit, and a timing controller circuit can easily be formed.

(Embodiment 2)

An active matrix substrate containing the NMOS thin film semiconductor device obtained in Embodiment 1 and used as a color LCD pixel switching element comprising 200 (line) x 320 (column) x 3 (color) = 192000 (pixels), the CMOS thin film semiconductor device obtained in Embodiment 1 and used as a 6-bit digital data driver (column measurement driver) and a scanning driver (line measurement driver) was manufactured. The digital driver of this embodiment comprises a clock signal line, a clock generator circuit, a shift register circuit, a NOR gate, a digital image signal line, a latch circuit 1, a latch pulse line, a latch circuit 2, a reset line 1, an AND gate, a standard potential line, a reset line 2, a 6-bit D/A converter based on volume division, a CMOS analog switch , a common potential line, and a source line reset transistor, the output from the CMOS analog switch being connected to the source line of the pixel portion. The

67

volume of the D/A converter satisfies the relation of $C_0 = C_1/2 = C_2/4 = C_3/8 = C_4/16 = C_5/32$. To the digital image signal line is directly input to the digital image signal output from a video random access memory (VRAM) of a computer. In the pixel portion of the active matrix substrate of this embodiment, the source electrode and source wiring, drain electrode (pixel electrode) comprise aluminum to form a reflection type LCD. A liquid crystal panel comprising the thus-formed active matrix substrate as one of a pair of substrates is manufactured. A polymer dispersion liquid crystal (PDLC) in which a black pigment is dispersed is used as a liquid crystal held between the pair of substrates to form a reflection type liquid crystal panel in a normally black mode (a black display when no voltage is applied to the liquid crystal). The thus-obtained liquid crystal panel is connected to external wiring to produce a liquid crystal display device. As a result, the NMOS and PMOS have substantially the same on resistance and transistor capacity, TFT has high performance, and the parasitic capacity of the transistor is very low. Further, since characteristics are uniform over the entire surface of the substrates, the 6-bit digital data driver and the scanning driver are normally operated over a wide operation range. Since the

pixel portion has a high degree of opening, even if black pigment dispersion PDLC is used, a high quality liquid crystal display device can be obtained. Further, since the manufacturing process of the active matrix substrate is stable, the liquid crystal display device can stably manufactured at low cost.

This liquid crystal display device is contained in a casing of a full-color portable personal computer (note PC). The active matrix substrate contains the 6-bit digital data driver, and a digital video signal is input directly into the liquid crystal display device form the computer, the circuit configuration is simplified, and at the same time, power consumption is significantly decreased. Since the liquid crystal thin film semiconductor device has high performance, the note PC is a good electronic apparatus having a very beauty display screen. In addition, on the basis of the fact that the liquid crystal display device is a reflection type having a high degree of opening, a back light is made unnecessary, thereby realizing decreases in the size and weight of a batter and long-term use. As a result, a very small lightweight electronic apparatus which can be used for a long time and which has a beauty display screen could be formed.

Although an example using the reflection type active matrix substrate had been described above, an embodiment of the present invention can be applied to a liquid crystal display device comprising a transmission type active matrix substrate. Fig. 9 shows the entire configuration of an example of such liquid crystal display devices. Namely, a liquid crystal display device comprises a back light 900, a polarizing plate 901, an active matrix substrate 903 provided with a driving circuit 902, a liquid crystal 904, a counter substrate 905 and a polarizing plate 906.

An electronic apparatus comprising the liquid crystal display device of this embodiment comprises a display information output source 1000, a display information processing circuit 1002, a display driving circuit 1004, a display panel 1006 such as a liquid crystal panel, a clock generator circuit 1008 and a power source circuit 1010. The display information output source 1000 comprises memory such as ROM and RAM, and a tuning circuit for tuning a television signal and outputting it so as to output display information such as a video signal on the basis of the clock generated from the clock generator circuit 1008. The display information processing circuit 1002 outputs display information on the basis of the clock

70

generated from the clock generator circuit 1008, The display information processing circuit 1002 comprises, for example, an amplification-polarity inversion circuit, a phase development circuit, a rotation circuit, a gammer correction circuit or clamp circuit. The display driving circuit 1004 comprises a scanning-side driving circuit and a data-side driving circuit to drive the liquid crystal panel 1006 to display an image. The power source circuit 1010 supplies electric power to each of the above circuits.

Examples of electronic apparatus having the above-described configuration include the liquid crystal projector shown in Fig. 11, a personal computer (PC) for multimedia and an engineering work station (EWS) shown in Fig. 12, the pager shown in Fig. 13, a portable telephone, a word processor, a television, a view finder type or monitor direct-viewing type video tape recorder, an electronic notebook, a table electronic computer, a car navigation device, POS terminal, a device with a touch panel, and the like.

The liquid crystal projector shown in Fig. 11 is a projection type projector comprising a transmission type liquid crystal panel as a light valve, for example, employs a three-plate prism optical system.

In the projector 1100 shown in Fig. 21, the projection light emitted from a white light source lamp unit 1102 is divided into the three primary colors R, G and B by a plurality of mirrors 1106 and two dichroic mirrors 1108 in a light guide 1104, and the three light parts are guided to three liquid crystal panels 1110R, 1110G and 1110B for respectively displaying images of the three colors. The light parts modulated by the liquid crystal panels 1110R, 1110G and 1110B are respectively incident on the dichroic prism 1112 in three directions. In the dichroic prism 1112, red light R and blue light B are bent at 90°, and green light straight travels to form an image of each color. As a result, a color image is projected on a screen through a projection lens 1114.

The personal computer 12000 shown in Fig. 12 comprises a body part 1204 having a key board 1202, and a liquid crystal display screen 1206.

The pager shown 1300 in Fig. 13 comprises a liquid crystal display substrate 1304, a liquid guide 1306 with a back light 1306a, a circuit substrate 1308, first and second shield plates 1310 and 1312, two elastic conductors 1313 and 1316, and a film carrier tape 1318, all of which are provided in a metallic frame. The two elastic conductors 1314 and 1316 and the film carrier tape 1318

are adapted for connecting the liquid crystal display substrate 1304 and the circuit substrate 1308.

In this apparatus, the liquid crystal display substrate 1304 comprises a liquid crystal held between two transparent substrates 1304a and 1304b to form at least a dot matrix type liquid crystal display panel. On one of the transparent substrates can be formed the driving circuit 1004 shown in Fig. 10 or the driving circuit 1004 and the display information processing circuit 1002. Circuits which are not provided on the liquid crystal display substrate 1304 can be provided as external circuits of the liquid crystal display substrate on the circuit substrate 1308 shown in Fig. 13.

Fig. 13 shows the configuration of the pager, and thus the circuit substrate 1308 other then the liquid crystal display substrate 1304 is required. However, when a liquid crystal display device is used as a component of an electronic apparatus and when a display driving circuit is mounted on a transparent substrate, the minimum unit of the liquid crystal display device is the liquid crystal display substrate 1304. Alternatively, the liquid crystal display substrate 1304 fixed to the metallic frame 1302 serving as a casing can also be used as a liquid crystal display device as a component of an electronic apparatus.

73

Further, in the case of a back light type, the liquid crystal display substrate 1304 and the light guide 1306 provided with the back light 1306a can be contained in the metallic frame 1302 to form a liquid crystal display device.

The present invention is not limited to the above embodiments, and various modifications can be made within the scope of the gist of the invention. For example, the present invention can be applied to not only the above-described various liquid crystal panels but also electroluminescence, plasma display devices.

Industrial Applicability

As described above, the high energy supply apparatus of the present invention is capable of stably producing high-quality crystallized films. The thus-obtained crystalline films can be applied to thin film electronic apparatus such as thin film semiconductor devices, and significantly improve the performance thereof. The present invention can thus produce a thin film semiconductor device with high performance by using a low temperature process in which for example, a low-price glass substrate can be used. When the present invention is applied to manufacture of an active matrix liquid

74

crystal display device, a high quality large liquid crystal display device can easily and stably be manufactured. Further, when the present invention is applied to manufacture of an electronic circuit, a high quality electronic circuit can easily stably be manufactured.

The thin film semiconductor device of the present invention is low priced and has high performance, and is thus optimum as an active matrix substrate of an active matrix liquid crystal display device. Particularly, the thin film semiconductor device is optimum as an active matrix containing a driver required to have high performance.

A liquid crystal display device to which the present invention is applied is low priced and has high performance, and is thus optimum as various displays including a full-color note PC.

The thin film electronic apparatus of the present invention is low priced and has high performance, and will be thus widely used for general purposes.